Synthetic Aperture Radar Image Simulation Of Collapsed Building Related To Multiple Signal

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ABSTRACT: SAR image simulation is a radar imaging simulation technique developed in recent years, which is of theoretical importance and practical value as it helps in the analysis design and verification of SAR systems, assists in SAR image interpretation, SAR image processing algorithm verification, and SAR image geometry correction. A collapsed model is used for synthetic aperture radar imaging simulations. Reflectivity maps corresponding to different types of radar backscatter signals are plotted. The correspondence between point and line features, different scattering signals, and object-specific structures in the simulated SAR images is analyzed according to different angles and in combination with the geometrical physical information of the target. The results show that the reflection level of the radar signal is closely related to the details of the object structure. The analysis of reflection intensity features in this paper provides a good basis for future inversion estimation of damage to earthquake-damaged buildings.

1. INTRODUCTION

SAR simulation systems can be broadly classified into SAR image simulators, which provide focal images directly, and SAR raw signal simulators, which provide raw SAR data for processing.

SAR imaging simulations focus on imaging principles and scattered electromagnetic field models of buildings. Representative studies include the urban SAR raw signal simulator developed by Franceschetti et al [1] and the application of the Kirchhoff approximation to compute multiple reflectance imaging [2].

SAR image simulation focuses on the use of high-quality 3D models of buildings and imaging geometry principles. Representative studies include Brunner et al [3] using the ray tracing method to reduce the computational time of imaging simulation.

In addition, Balz et al [4] developed SARVIZ, a high-resolution SAR image simulation software based on the raster method; Hammer et al [5] developed ray-tracing based CohRaS software. Auer et al [6] developed RaySAR software that simulates reflectance maps by ray tracing method to achieve SAR image simulation. A comparative analysis of the three simulation software, SARVIZ, CohRaS, and RaySAR, can be found in the paper [7].

On the other hand, although theoretical equations for the propagation and reflection characteristics of radar have been established in this field, the correspondence with real structures with various structures, applications, and shapes has not necessarily been clarified. In particular, digital data before and after natural disasters, such as collapsed houses and damaged structures, have not been preserved.

This thesis uses a collapsed model simulated by the software Wallstat to have a preliminary simulation of a collapsed building as well as a reflection map analysis.

This research provides the basis for the future realization of theoretical calculations of radar reflection properties, reproduction of various types of buildings in digital space, and the creation of a database of SAR simulations under different measurement conditions.

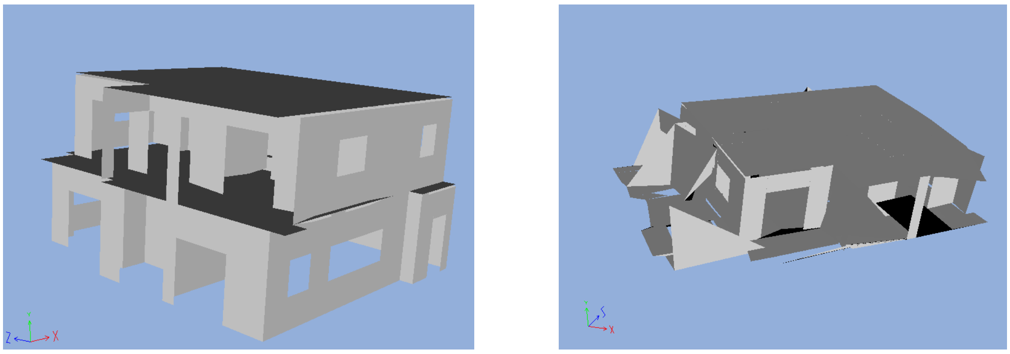
This paper is organized as follows. The first section briefly describes the current status of SAR simulation systems. Section 2 provides information on the photogrammetric survey, the 3D modeling, and the simulation procedure. Section 3 gives the analysis of the simulation results with the case study (a collapsed building model). Then section 4 concludes this paper and discusses future work.

2. SAR IMAGE SIMULATION AND 3D MODEL

RaySAR is a 3D SAR simulator based on the ray tracing method and is an extension of the open-source software POV-Ray, which is meant to simulate radar signals in 3D, i.e. azimuth, distance, and elevation angles. Thus, the simulated signal contribution can be compared with the object geometry reconstructed by interferometric SAR methods. The POV-Ray ray tracer provides artificial SAR data without phase noise. For introducing an artificial error, phase noise can be added to the complex signal [7]. To make it easier to observe the results, the noise was not added to this study.

The numerical model used to analyze the reflection characteristics of the collapsed model was developed by the Wallstat software, which was developed by the Building Research Institute of Japan. Wallstat is a computer program that uses the theory of the DEM and analyzes the likelihood of collapsed behavior of the wooden frame under seismic motion.[8]

Figure 1 shows the 3D models from Wallstat used for this research. On the left is a structurally simple wooden 2-story building, and on the right is the output model after the collapse was set up in Wallstat.



(a) 3D building model (b) 3D collapsed building model

Fig.1 3D model (Wallstat)

3. RESULTS AND DISCUSSIONS

Figures 2 to 5 show the simulation results of this collapsed building model, including reflectivity map, histogram map, elevation map, and simulated spatial distribution of intensities.

In addition Figures, 2 to 5 show the results using RaySAR at a 30-degree elevation angle. The images are sampled at a 45-degree interval over a full 360-degree azimuth coverage (at 0, 45, 90, 135, 180, 225, 270, and 315 degrees).

The imaging geometry of the virtual SAR, i.e. the angle of incidence and the heading angle, is adapted to the TerraSAR-X orbit. To this end, the uncollapsed model is rotated.

From the figures of the simulated spatial distribution of intensities, we can observe the different scattering techniques present in each part of the building model. For better understanding, the different colors reflect the class of scattering centers detected. (blue: single bounce; green: double bounce; red: triple bounce; magenta: fourfold bounce; cyan: fivefold bounce; white: no signal response)

The results of the collapsed model are very irregular in terms of multiple reflections compared to the uncollapsed model. The edges of the building, and where the first and second floors meet, show a large number of multiple reflections. The walls are the same as the flat structure and therefore still produce single reflections of signals.

The reflections at different azimuth angles produce different multiple reflections as the angle changes, except for the reflections from the wall consisting of a flat surface (the top layer), which are essentially the same, and the reflections from the collapsed part as an object. Inspection of the results at 0 and 45 degrees shows that after a rotation of 45 degrees, a large number of triple bounce reflections (in red) appear in the middle of the closer edges, as shown by the white circle. Looking at the results at 90 and 135 degrees one can tell that there are triple bounce, fourfold bounce, and fivefold bounce to the right of the building, and in the experiment at 135 degrees after the rotation, these multiple reflections are still present, but the reflection results change with the angle. As shown by the black circle.

The theoretical scattering in general is, single bounce (flat-plate), double bounce (dihedral), triple bounce (trihedral), edge diffraction (cylinder and top hat), cavity (hollow cylinder), and shadowing (obstructions between parts on the target).

We can conclude that the results of this simulation show agreement with the theoretical predictions.

4. CONCLUSIONS

A 3-dimensional model of the collapsed building was used for synthetic aperture radar imaging simulations. Reflectance maps corresponding to signals with different bounce counts, histogram maps, and elevation maps were plotted.

The authors analyze the correspondence between points, line features, different types of radar backscatter signals, and object specific structures in the simulated SAR images in conjunction with the geometrical physical information of the target. The results of this simulation are consistent with the theoretical predictions of radar reflections.

This research provides the basis for the future realization of theoretical calculations of radar reflection properties, reproduction of various types of buildings in digital space, and the creation of a database of SAR simulations under different measurement conditions.

As future work, this study will add the study of the reflection characteristics of collapsed models and attempt to generalize the correspondence between structures and reflection characteristics.

5. ACKNOWLEDGMENT

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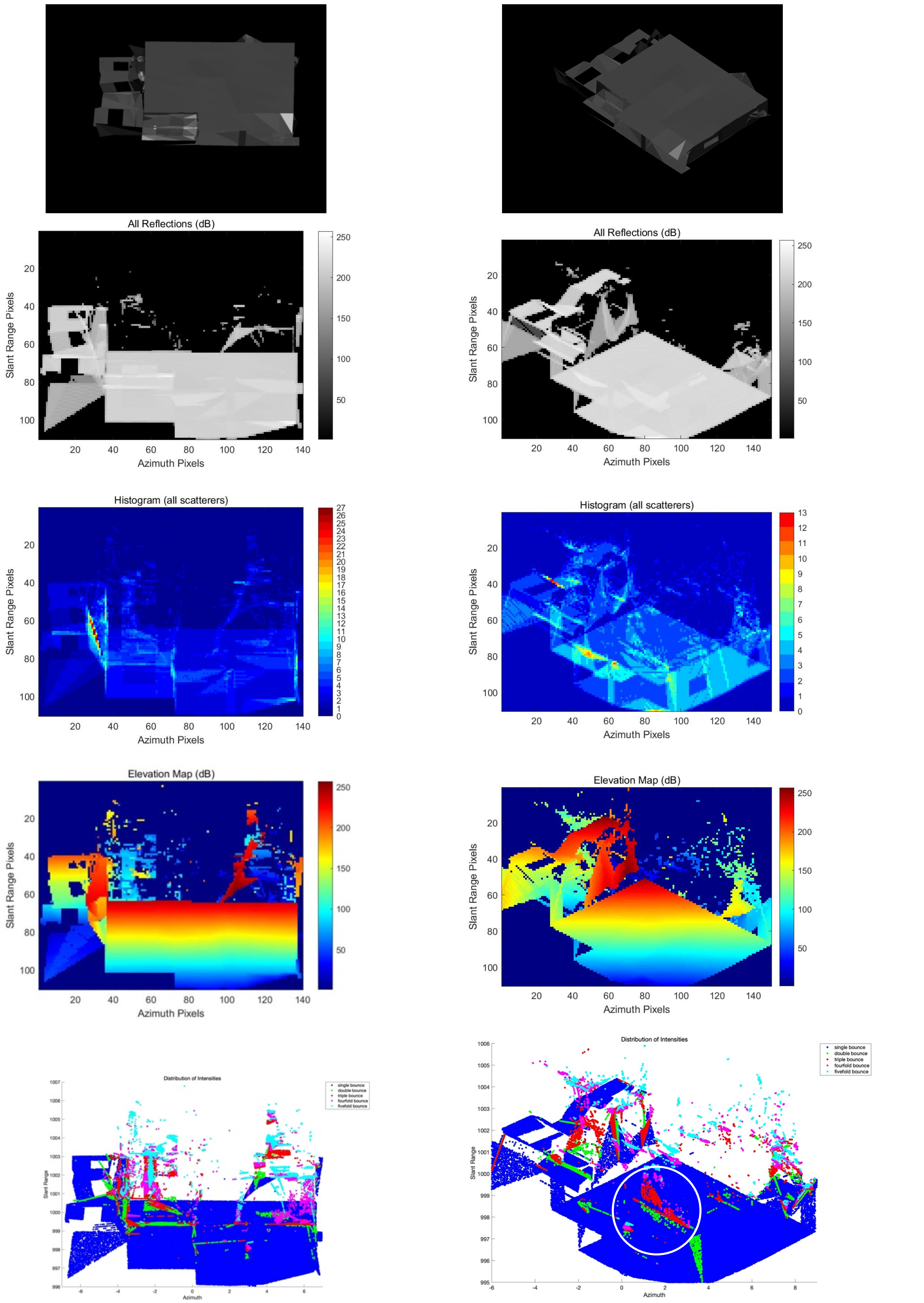
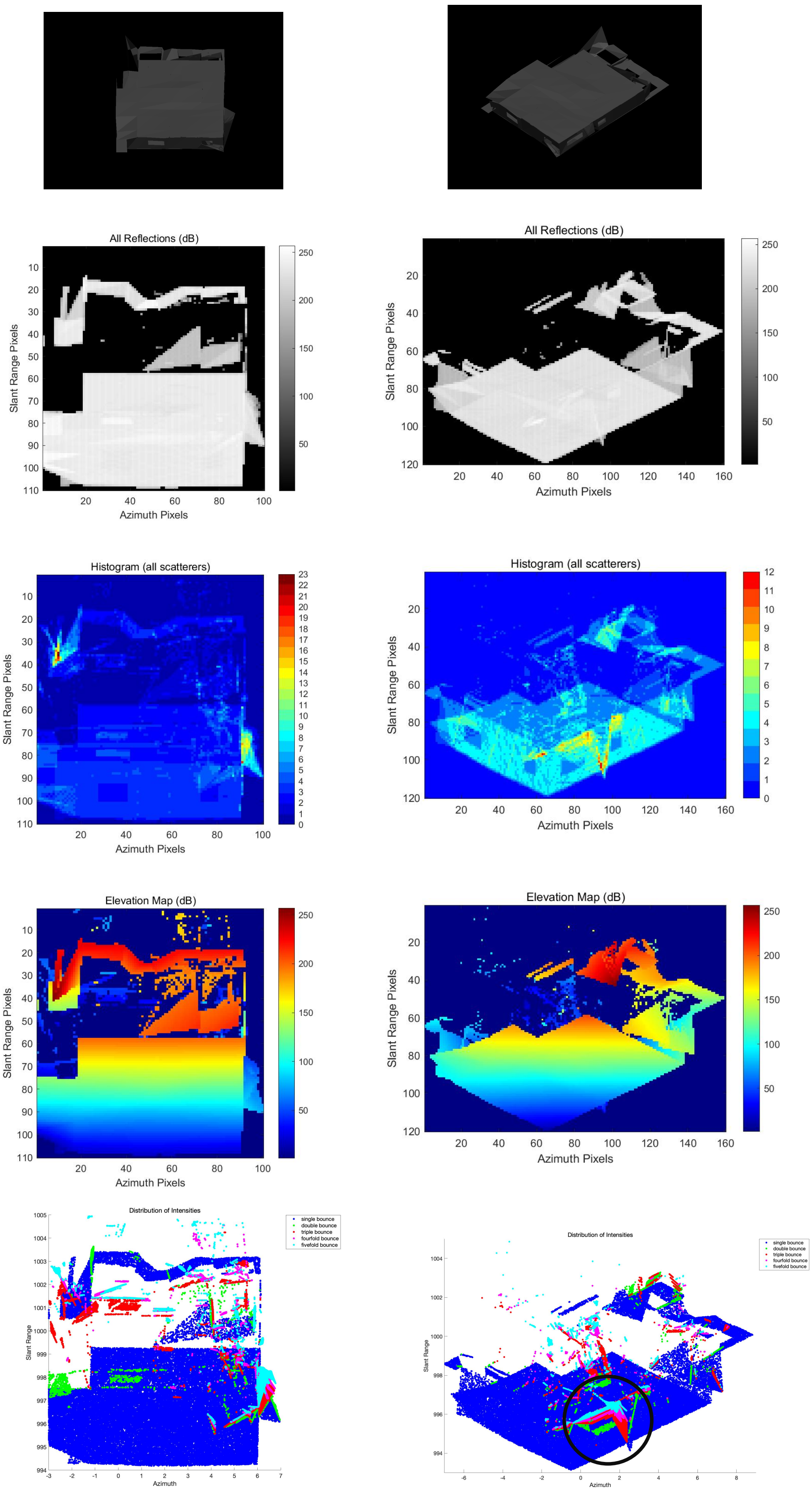


(a) 0 deg (b) 45 deg

Fig.2 Simulation results at a 30-degree elevation angle.

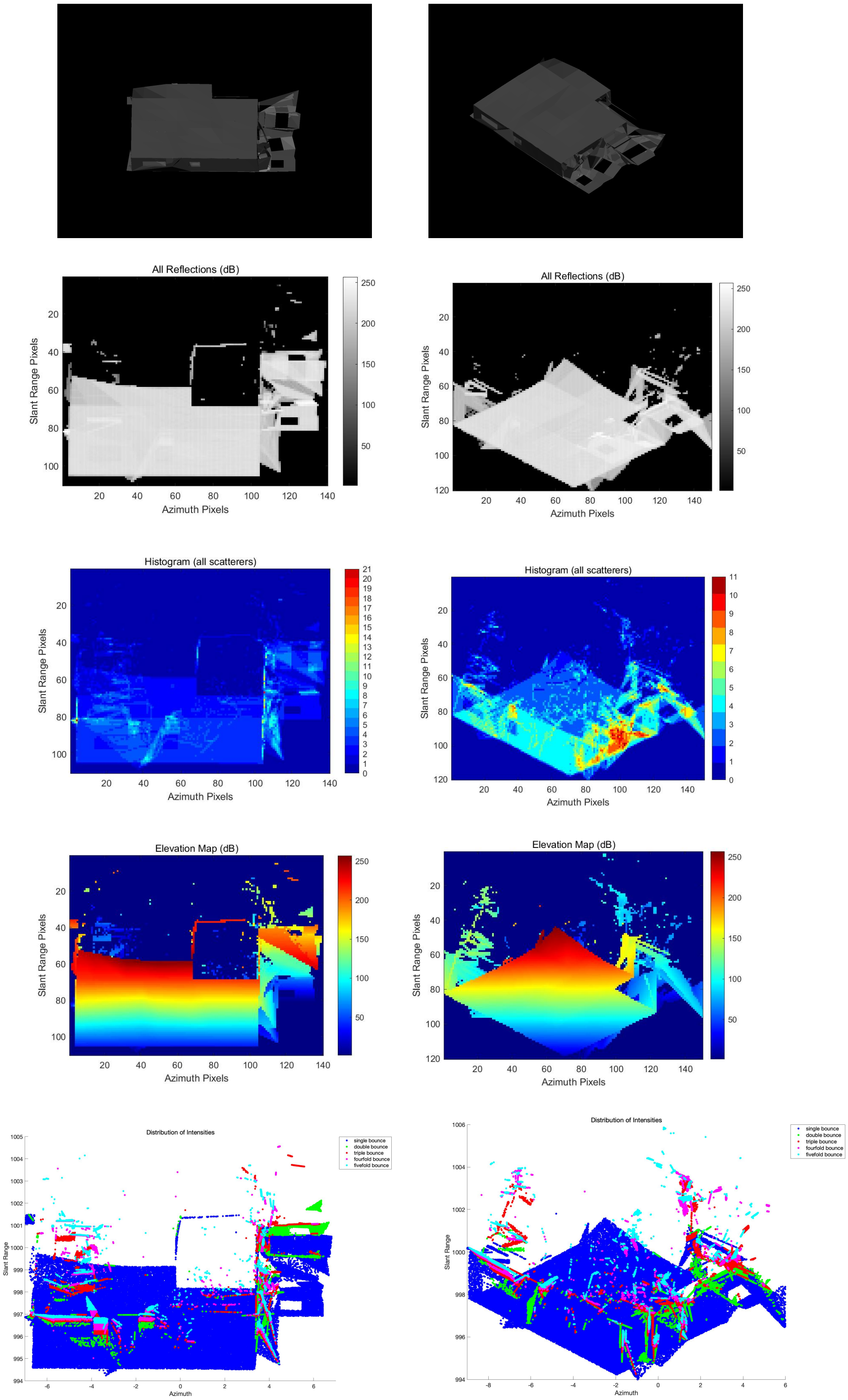
(Up to down: collapsed building model with different Azimuth viewing angles; Reflectivity map; Histogram Map; Elevation Map; Simulated spatial distribution of intensities.)



(a) 90 deg (b) 135 deg

Fig.3 Simulation results at a 30-degree elevation angle.

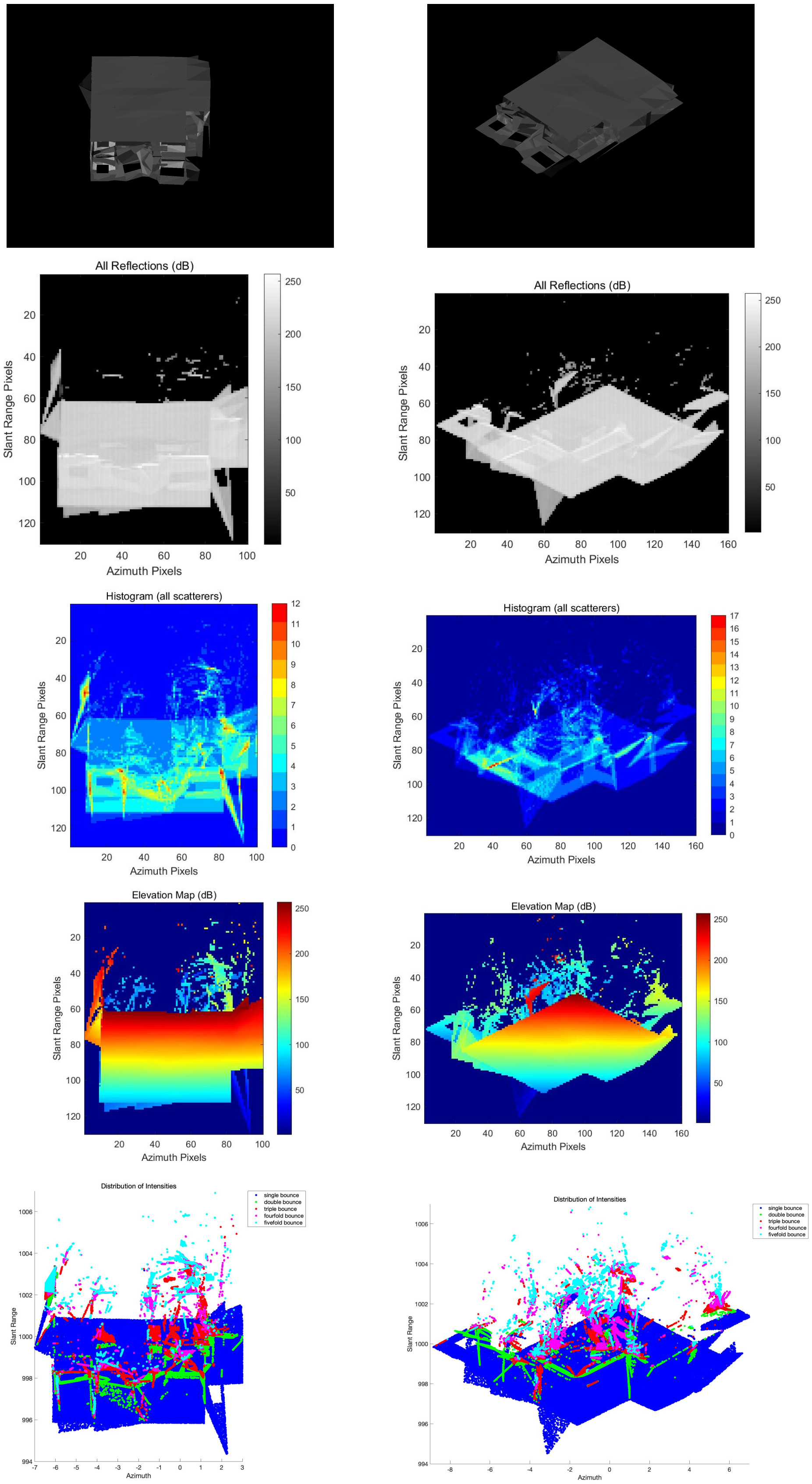
(Up to down: collapsed building model with different Azimuth viewing angles; Reflectivity map; Histogram Map; Elevation Map; Simulated spatial distribution of intensities.)



(a) 180 deg (b) 225 deg

Fig.4 Simulation results at a 30-degree elevation angle.

(Up to down: collapsed building model with different Azimuth viewing angles; Reflectivity map; Histogram Map; Elevation Map; Simulated spatial distribution of intensities.)



(a) 270 deg (b) 315 deg

Fig.5 Simulation results at a 30-degree elevation angle.

(Up to down: collapsed building model with different Azimuth viewing angles; Reflectivity map; Histogram Map; Elevation Map; Simulated spatial distribution of intensities.)